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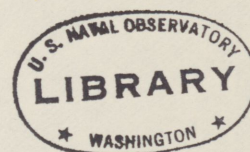
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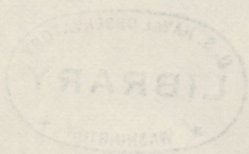
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SUNSPOT * AREAS 1907 - 1970

by



R. S. Harrington and M. Miranian



SUNSPOT AREAS 1907-1970

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INTRODUCTION: Since 1907 the U. S. Naval Observatory has been taking daily photographs of the Sun for the purpose of determining sunspot positions, areas, counts, and types. The emphasis of the program has been on determining areas, since it is hoped that the measurement of areas will be less affected by personal effects than the counting of spots. This present Circular summarizes the program and its results through 1970 and compares the area measurements with the more familiar Zurich mean daily sunspot numbers.

The results from the program have been published in a variety of places. Through 1927 they appeared in the Publications of the U. S. Naval Observatory, Vol. XII, 2nd series. The interval 1928 through 1947 was covered in the Monthly Weather Review of the U. S. Weather Bureau, and 1948 through August 1957, in various issues of this Circular. After August 1957, the results were not formally published but were mailed out individually to interested parties. Initially, these reports contained data on counts, positions, and types, as well as areas, but from 1968 through 1970, only daily and mean monthly areas were distributed. In addition, Circular 30 of this series, by Wm. Markowitz, gives a discussion of the program and a limited analysis of the material through 1950. Circular 30 also contains some basic definitions and a summary of related solar publications.

INSTRUMENTATION AND TECHNIQUE: The instrument used to obtain the Washington plates is a horizontal photoheliograph with a 5-inch Clark lens of 40-foot focal length. In normal operation the lens is stopped down to 2 inches, both to increase the depth of field and to allow longer exposure times. The instrument has always been on the grounds of the Naval Observatory in Washington, D. C. Initially, it was installed in a building of its own south of the 26-inch dome, and at that time had only a single mirror mounted directly in front of the lens to reflect sunlight into the telescope. In 1953 the instrument was moved to the South Transit House, and a second mirror was added to the system to put north at the top of the plate. In late 1965 the telescope was moved to the roof of the Simon Newcomb Laboratory, its present location, and the second mirror was removed, restoring the instrument to its original configuration.

In the present configuration, the telescope is horizontally mounted and pointed north. The lens can be moved along the axis of

the telescope to adjust the focus with temperature. The standard time of the exposure is determined to the nearest second and converted to true local solar time so that the orientation of the image on the plate can be computed. Blue sensitive plates are used without a filter.

An attempt has been made to photograph the Sun daily, weather permitting. Through August 1957 Mount Wilson sent a daily plate taken with the 60-foot tower telescope, and this was used whenever a plate was not obtained at Washington. Thus Mount Wilson plates comprise about 20% of the data prior to 1957. Markowitz's analysis of the material prior to 1951 shows that there are no serious differences between the areas obtained from the two sets of plates, but that the Mount Wilson plates showed a significantly higher spot count. The better seeing at Mount Wilson makes possible the detection of many smaller spots which do not contribute significantly to the total area.

Areas and positions are measured by superimposing the solar plate over a clear glass plate with a photographically produced grid of solar latitude and longitude. There is a series of grids for measuring positions, the variations between grids reflecting both the varying size of the apparent solar disk and the variation in the tilt of the pole of the Sun. A new set of grids was made up and put into use in 1954, but there has been no careful check for consistency with the older grids.

The algorithm for determining the orientation of the solar image on the plate is as follows. First, the direction of north on the plate must be determined. If θ is the hour angle of the Sun, δ the declination of the Sun, ϕ the latitude of the telescope, the following angles can be determined (Figure I):

$$\cos(t) = \sin(\delta)\cos(\phi) - \cos(\delta)\sin(\phi)\cos(\theta)$$

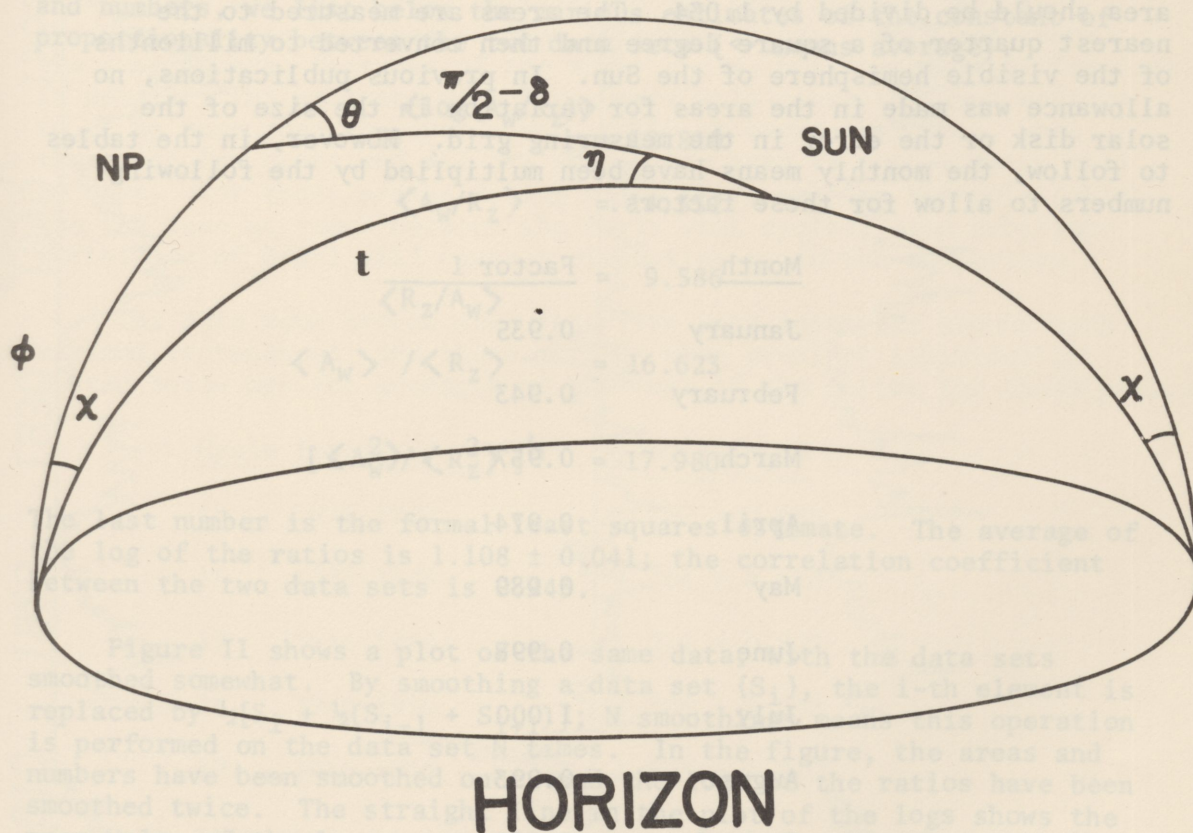
$$\sin(\eta) = \frac{\sin(\phi)\sin(\theta)}{\sin(t)}$$

$$\sin(\chi) = \frac{\cos(\delta)\sin(\theta)}{\sin(t)}$$

Then $\gamma = \eta - \chi$ is the angle from the top of the plate to north, measured counterclockwise. If P is the position angle of the North Pole of the Sun, taken from the American Ephemeris and Nautical Almanac, then $A = P + \gamma$ is the angle from the vertical on the plate to the North Pole of the Sun.

The actual measurement of the plate occurs in two steps. An appropriate grid is inserted into the undercarriage of the measuring machine and the

FIGURE I



solar plate in the upper bracket, which is oriented by rotation through the angle A. The positions of the spots are determined by comparison with a grid showing lines of latitude and longitude on the Sun at ten degree intervals, the positions being recorded to the nearest degree. There are 22 such grids, covering the entire range of apparent solar diameter and inclination of the pole. The areas of the spots are measured using a single grid with lines of latitude and longitude spaced in such a way that every square on the grid corresponds to one square degree on the surface of the Sun, thus eliminating the need for a foreshortening correction. This grid was made to coincide with the solar disk when the Sun is at maximum distance from the Earth. To reduce area measures to mean distance from the Earth, the area should be divided by 1.034. The areas are measured to the nearest quarter of a square degree and then converted to millionths of the visible hemisphere of the Sun. In previous publications, no allowance was made in the areas for variation in the size of the solar disk or the error in the measuring grid. However, in the tables to follow, the monthly means have been multiplied by the following numbers to allow for these factors.

<u>Month</u>	<u>Factor</u>
January	0.935
February	0.943
March	0.957
April	0.974
May	0.989
June	0.998
July	1.000
August	0.993
September	0.978
October	0.961
November	0.945
December	0.935

The spot counts and Waldmeier group types are determined by visual inspection.

RESULTS: Table I summarizes the results of the program to date. In this table we list the monthly mean sunspot area A_w , expressed in millionths of the visible solar hemisphere. For comparison, we also give the Zurich mean daily sunspot number R_z , and the log of the ratio of the Washington area to the Zurich number. For comparison purposes, the logs of the ratios are considered, rather than the ratios themselves, since the behavior of the logs is independent of the order of the ratio. Yearly means are also given for all three quantities; note that the mean of the logs of the ratios is not the same as the log of the ratio of the means. Also note that the ratio 0/0 has been defined as 1.

To show the effect of various ways of comparing sunspot areas and numbers, we list below the various estimates of the constant of proportionality between the two data sets ($\langle \rangle$ means average).

$$10 \langle \log(A_w/R_z) \rangle = 12.810$$

$$\langle A_w/R_z \rangle = 14.552$$

$$\frac{1}{\langle R_z/A_w \rangle} = 9.586$$

$$\langle A_w \rangle / \langle R_z \rangle = 16.623$$

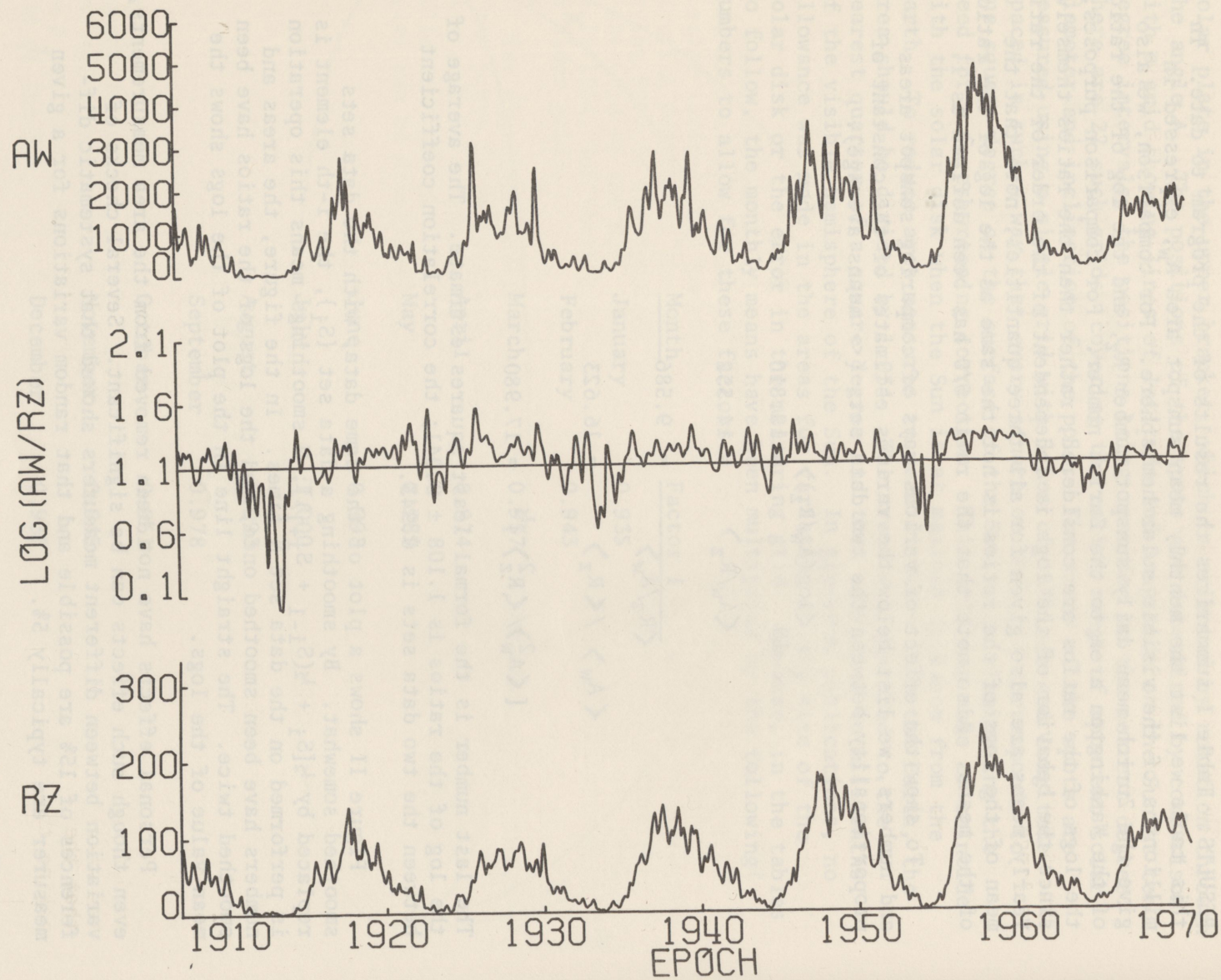
$$[\langle A_w^2 \rangle / \langle R_z^2 \rangle]^{1/2} = 17.980$$

The last number is the formal least squares estimate. The average of the log of the ratios is 1.108 ± 0.041 ; the correlation coefficient between the two data sets is 0.943.

Figure II shows a plot of the same data, with the data sets smoothed somewhat. By smoothing a data set $\{S_i\}$, the i -th element is replaced by $\frac{1}{2}[S_i + \frac{1}{2}(S_{i-1} + S_{i+1})]$; N smoothings means this operation is performed on the data set N times. In the figure, the areas and numbers have been smoothed once, and the logs of the ratios have been smoothed twice. The straight line in the plot of the logs shows the mean value of the logs.

Personal effects have not been removed from the area measurements, even though such effects can be significant. Several checks of variation between different measurers showed that systematic differences of 15% are possible and that random variations for a given measurer are typically 5%.

The Washington area measures have also been compared with the Greenwich area measures from 1907 through 1953 and from 1956 through



1961. The average of the log of the ratios for these data sets is 0.017 ± 0.004 , indicating the Washington areas are systematically higher by a factor of 1.041. The correlation coefficient is 0.985, showing that the two data sets are very similar. The primary causes of the variation between the two sets can be traced to two things. To begin with, there were relatively few sunspots during the first two cycles covered by the Washington data, so the statistical uncertainty is larger. Second, there is some indication that during the 1950's the Washington areas were systematically higher than the Greenwich areas by another 10% over the mean difference.

The comparison of the Washington areas with the Zurich numbers shows there are variations between the two sets of data that are greater than can be expected from internal errors. Both sets show the same general features of the solar cycle, but there are differences in detail. The presence of a large spot will cause the area measure to go up more than the spot count, while at sunspot minimum, when there are few spots and all are small, the area to number ratio will go down. For those months during which there were no sunspots (which was the case at times between the early weak cycles), the arbitrary definition of $0/0=1$ will cause a discontinuity in the comparison.

The data were broken down into five year intervals around each maximum represented, and these periods were examined individually. Listed below are the averages of the logs of the ratios for those periods.

	<u>Cycle Interval</u>		<u>$\langle \log(A_w/R_z) \rangle$</u>
1909	15	1916-1920	1.187 ± 0.038
	16	1925-1929	1.264 ± 0.028
	17	1936-1940	1.219 ± 0.029
	18	1946-1950	1.208 ± 0.018
	19	1956-1960	1.295 ± 0.010

It can be seen that, as the cycles get stronger, the uncertainties become smaller, and that for the last, very strong cycle the ratio is considerably larger than normal (by about 50%). Part of this may be due to the systematic internal trend suggested earlier, but part of the effect is real. A closer examination of the 56-60 interval reveals that there were always large spots on the Sun during that cycle, making the monthly mean both larger and more uniform.

CONCLUSIONS: We have presented a continuous series of measurements of sunspot areas covering 64 years. Because of the uncertainties and fluctuations in day to day measures, the results have been given only as monthly means. Area measures are not as free of personal effects as might be hoped, but the data seem to be reasonably consistent and homogeneous. Measurements of areas show the same general features in the solar cycle as do counts of spots, but there is considerable difference in detail. Nothing so far has suggested that one index is clearly superior to the other for monitoring the Sun for long periods of time.

The comparison of the Washington areas with the Zurich numbers shows there are variations between the two sets of data that are greater than can be expected from internal errors. Both sets show the same general features of the solar cycle, but there are differences in detail. The presence of a large spot will cause the area measure to go up more than the spot count, while at sunspot minimum, when there are few spots and all are small, the area to number ratio will be low. For those months during which there were no sunspots (which was the case at times between the early weak cycles) the arbitrary definition of 0.0-1 will cause a discontinuity in the comparison.

The data were broken down into five year intervals around each maximum represented, and these periods were examined individually. Listed below are the averages of the logs of the ratios for those periods.

Cycle Interval	$\log(A/R)$
15 1916-1920	-1.187 ± 0.038
16 1925-1929	-1.164 ± 0.038
17 1936-1940	-1.219 ± 0.039
18 1946-1950	-1.208 ± 0.018
19 1956-1960	-1.295 ± 0.010

It can be seen that, as the cycles get stronger, the uncertainties become smaller, and that for the last, very strong cycle the ratio is considerably larger than normal (by about 50%). Part of this may be due to the systematic internal trend suggested earlier, but part of the effect is real. A closer examination of the 56-60 interval reveals that there were always large spots on the Sun during that cycle, making the monthly mean both larger and more uniform.

TABLE I - MONTHLY SUNSPOT AREAS AND NUMBERS

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YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1907	1187	76.4	1.191	1911	43	3.4	1.102
	2417	108.2	1.349		91	9.0	1.005
	641	60.7	1.024		97	7.8	1.095
	669	52.6	1.104		290	16.5	1.245
	656	42.9	1.184		78	9.0	0.938
	909	40.4	1.352		21	2.2	0.980
	779	49.7	1.195		6	3.5	0.234
	813	54.3	1.175		18	4.0	0.653
	1274	85.0	1.176		81	4.0	1.306
	1258	65.4	1.284		13	2.6	0.699
	1001	61.5	1.212		38	4.2	0.957
	867	47.3	1.263		11	2.2	0.699
MEAN	1039	62.0	1.209	MEAN	66	5.7	0.909
1908	459	39.2	1.069	1912	0	0.3	0.0
	279	33.9	0.915		0	0.0	0.0
	245	28.7	0.931		45	4.9	0.963
	663	57.6	1.061		48	4.5	1.028
	375	40.8	0.963		30	4.4	0.834
	555	48.1	1.062		65	4.1	1.200
	361	39.5	0.961		9	3.0	0.477
	1592	90.5	1.245		0	0.3	0.0
	1567	86.9	1.256		5	9.5	-0.279
	357	32.3	1.043		48	4.6	1.018
	673	45.5	1.170		4	1.1	0.561
	543	39.5	1.138		56	6.4	0.942
MEAN	639	48.5	1.068	MEAN	26	3.6	0.562
1909	1322	56.7	1.368	1913	27	2.3	1.070
	897	46.6	1.284		10	2.9	0.538
	944	66.3	1.153		0	0.5	0.0
	408	32.3	1.101		0	0.9	0.0
	566	36.0	1.197		0	0.0	0.0
	247	22.6	1.039		0	0.0	0.0
	489	35.8	1.135		0	1.7	0.0
	99	23.1	0.632		0	0.2	0.0
	914	38.8	1.372		3	1.2	0.398
	728	58.4	1.096		20	3.1	0.810
	797	55.8	1.155		10	0.7	1.155
	1100	54.2	1.307		34	3.8	0.952
MEAN	709	43.9	1.153	MEAN	9	1.4	0.410
1910	261	26.4	0.995	1914	9	2.8	0.507
	999	31.5	1.501		14	2.6	0.731
	299	21.4	1.145		45	3.1	1.162
	48	8.4	0.757		282	17.3	1.212
	304	22.2	1.137		63	5.2	1.083
	64	12.3	0.716		162	11.4	1.153
	180	14.1	1.106		49	5.4	0.958
	194	11.5	1.227		311	7.7	1.606
	710	26.2	1.433		343	12.7	1.431
	402	38.3	1.021		43	8.2	0.720
	14	4.9	0.456		182	16.4	1.045
	24	5.8	0.617		256	22.3	1.060
MEAN	292	18.6	1.009	MEAN	147	9.6	1.056

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YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1915	389	23.0	1.228	1919	771	48.1	1.205
	712	42.3	1.226		1491	79.5	1.273
	550	38.8	1.152		1249	66.5	1.274
	908	41.3	1.342		863	51.8	1.222
	580	33.0	1.245		1547	88.1	1.245
	1101	68.8	1.204		1840	111.2	1.219
	1388	71.6	1.287		726	64.7	1.050
	931	69.6	1.126		1222	69.0	1.248
	606	49.5	1.088		1151	54.7	1.323
	585	53.5	1.039		867	52.8	1.215
	346	42.5	0.911		591	42.0	1.148
	317	34.5	0.963		533	34.9	1.184
MEAN	701	47.4	1.151	MEAN	1071	63.6	1.217
1916	512	45.3	1.053	1920	1074	51.1	1.323
	552	55.4	0.998		859	53.9	1.202
	804	67.0	1.079		1338	70.2	1.280
	698	71.8	0.988		291	14.8	1.294
	981	74.5	1.120		403	33.3	1.083
	1094	67.7	1.208		660	38.7	1.232
	419	53.5	0.894		379	27.5	1.139
	317	35.2	0.955		252	19.2	1.118
	459	45.1	1.008		777	36.3	1.331
	681	50.7	1.128		741	49.6	1.174
	542	65.6	0.917		720	27.2	1.423
	876	53.0	1.218		498	29.9	1.222
MEAN	661	57.1	1.047	MEAN	666	37.6	1.235
1917	1151	74.7	1.188	1921	461	31.5	1.165
	2386	71.9	1.521		294	28.3	1.017
	1468	94.8	1.190		427	26.7	1.204
	1193	74.7	1.203		491	32.4	1.181
	1521	114.1	1.125		890	22.2	1.603
	1943	114.9	1.228		555	33.7	1.217
	1657	119.8	1.141		664	41.9	1.200
	3499	154.5	1.355		348	22.8	1.184
	2468	129.4	1.280		551	17.8	1.491
	1203	72.2	1.222		435	18.2	1.378
	1327	96.4	1.139		658	17.8	1.568
	2727	129.3	1.324		466	20.3	1.361
MEAN	1879	103.9	1.243	MEAN	520	26.1	1.297
1918	2144	96.0	1.349	1922	100	11.8	0.928
	1021	65.3	1.194		496	26.4	1.274
	992	72.2	1.138		1290	54.7	1.373
	701	80.5	0.940		85	11.0	0.888
	785	76.7	1.010		95	8.0	1.075
	436	59.4	0.866		29	5.8	0.699
	1516	107.6	1.149		149	10.9	1.136
	1919	101.7	1.276		77	6.5	1.074
	919	79.9	1.061		81	4.7	1.236
	1347	85.0	1.200		81	6.2	1.116
	898	83.4	1.032		238	7.4	1.507
	965	59.2	1.212		710	17.5	1.608
MEAN	1137	80.6	1.119	MEAN	286	14.2	1.159

TABLE I - MONTHLY SUNSPOT AREAS AND NUMBERS

YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1923	139	4.5	1.490	1927	1672	81.6	1.312
	2	1.5	0.125		1431	93.0	1.187
	26	3.3	0.896		966	69.6	1.142
	32	6.1	0.720		1282	93.5	1.137
	25	3.2	0.893		1013	79.1	1.107
	111	9.1	1.086		938	59.1	1.201
	37	3.5	1.024		769	54.9	1.146
	3	0.5	0.778		832	53.8	1.189
	166	13.2	1.100		1061	68.4	1.191
	121	11.6	1.018		835	63.1	1.122
	110	10.0	1.041		1165	67.2	1.239
	15	2.8	0.729		554	45.2	1.088
MEAN	66	5.8	0.908	MEAN	1043	69.0	1.172
1924	0	0.5	0.0	1928	1498	83.5	1.254
	42	5.1	0.916		1171	73.5	1.202
	51	1.8	1.452		1774	85.4	1.317
	200	11.3	1.248		1540	80.6	1.281
	278	20.8	1.126		1354	76.9	1.246
	518	24.0	1.334		1393	91.4	1.183
	365	28.1	1.114		2133	98.0	1.338
	450	19.3	1.368		1700	83.8	1.307
	530	25.1	1.325		2229	89.7	1.395
	506	25.6	1.296		1002	61.4	1.213
	575	22.5	1.407		818	50.3	1.211
	253	16.5	1.186		1070	59.0	1.259
MEAN	314	16.7	1.148	MEAN	1474	77.8	1.267
1925	56	5.5	1.008	1929	993	68.9	1.159
	303	23.2	1.116		859	64.1	1.127
	208	18.0	1.063		1003	50.2	1.301
	350	31.7	1.043		969	52.8	1.264
	807	42.8	1.275		954	58.2	1.215
	892	47.5	1.274		1365	71.9	1.278
	586	38.5	1.182		1091	70.2	1.191
	659	37.9	1.240		822	65.8	1.097
	767	60.2	1.105		296	34.4	0.935
	1323	69.2	1.281		1267	54.0	1.370
	1856	58.6	1.501		2477	81.1	1.485
	3804	98.6	1.586		3129	108.0	1.462
MEAN	968	44.3	1.223	MEAN	1269	65.0	1.240
1926	2912	71.8	1.608	1930	1213	65.3	1.269
	2163	70.0	1.490		782	49.2	1.201
	1583	62.5	1.404		748	35.0	1.330
	572	38.5	1.172		623	38.2	1.212
	1277	64.3	1.298		481	36.8	1.116
	1607	73.5	1.340		277	28.8	0.983
	1008	52.3	1.285		162	21.9	0.869
	1335	61.6	1.336		298	24.9	1.078
	1526	60.8	1.400		370	32.1	1.062
	1591	71.5	1.347		612	34.4	1.250
	777	60.5	1.109		618	35.6	1.240
	1695	79.4	1.329		206	25.8	0.902
MEAN	1504	63.9	1.343	MEAN	533	35.7	1.126

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YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1931	146	14.6	1.000	1935	249	18.9	1.120
	789	43.1	1.263		250	20.5	1.086
	457	30.0	1.183		158	23.1	0.835
	374	31.2	1.079		110	12.2	0.955
	273	24.6	1.045		317	27.3	1.065
	145	15.3	0.977		629	45.7	1.139
	113	17.4	0.813		540	33.9	1.202
	92	13.0	0.850		452	30.1	1.177
	158	19.0	0.920		603	42.1	1.156
	97	10.0	0.987		886	53.2	1.222
	266	18.7	1.153		1465	64.2	1.358
	219	17.8	1.090		1552	61.5	1.402
MEAN	261	21.2	1.030	MEAN	601	36.1	1.143
1932	119	12.1	0.993	1936	1599	62.8	1.406
	141	10.6	1.124		1233	74.3	1.220
	173	11.2	1.189		1176	77.1	1.183
	278	11.2	1.395		1069	74.9	1.154
	421	17.9	1.371		787	54.6	1.159
	432	22.2	1.289		1065	70.0	1.182
	120	9.6	1.097		709	52.3	1.132
	97	6.8	1.154		936	87.0	1.032
	5	4.0	0.097		968	76.0	1.105
	72	8.9	0.908		1129	89.0	1.103
	179	8.2	1.339		2064	115.4	1.253
	249	11.0	1.355		1719	123.4	1.144
MEAN	191	11.1	1.109	MEAN	1205	79.7	1.173
1933	226	12.3	1.264	1937	2237	132.5	1.227
	619	22.2	1.445		1791	128.5	1.144
	157	10.1	1.192		1102	83.9	1.118
	21	2.9	0.860		1862	109.3	1.231
	23	3.2	0.857		2066	116.7	1.248
	37	5.2	0.852		2582	130.3	1.297
	7	2.8	0.398		3268	145.1	1.353
	1	0.2	0.699		2217	137.7	1.207
	20	5.1	0.593		1422	100.7	1.150
	25	3.0	0.921		2071	124.9	1.220
	2	0.6	0.523		856	74.4	1.061
	2	0.3	0.824		1171	88.8	1.120
MEAN	95	5.7	0.869	MEAN	1887	114.4	1.198
1934	15	3.4	0.645	1938	1965	98.4	1.300
	46	7.8	0.771		1620	119.2	1.133
	5	4.3	0.066		1486	86.5	1.235
	316	11.3	1.447		2163	101.0	1.331
	335	19.7	1.231		2267	127.4	1.250
	83	6.7	1.093		1304	97.5	1.126
	102	9.3	1.040		2937	165.3	1.250
	109	8.3	1.118		1573	115.7	1.133
	13	4.0	0.512		1619	89.6	1.257
	27	5.7	0.675		1872	99.1	1.276
	66	8.7	0.880		2251	122.2	1.265
	121	15.4	0.895		1721	92.7	1.269
MEAN	103	8.7	0.864	MEAN	1898	109.5	1.236

TABLE I - MONTHLY SUNSPOT AREAS AND NUMBERS

YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1939	1147	80.3	1.155	1943	126	12.4	1.007
	1047	77.4	1.131		591	28.9	1.311
	812	64.6	1.099		666	27.4	1.386
	2078	109.1	1.280		721	26.1	1.441
	1844	118.3	1.193		282	14.1	1.301
	1381	101.0	1.136		68	7.6	0.952
	2189	97.6	1.351		257	13.2	1.289
	2571	105.8	1.386		163	19.4	0.924
	3303	112.6	1.467		248	10.0	1.394
	2048	88.1	1.366		222	7.8	1.454
	1165	68.1	1.233		163	10.2	1.204
	547	42.1	1.114		318	18.8	1.228
MEAN	1678	88.7	1.243	MEAN	319	16.3	1.241
1940	957	50.5	1.278	1944	26	3.7	0.847
	928	59.4	1.194		1	0.5	0.301
	1453	83.3	1.242		124	11.0	1.052
	694	60.7	1.058		2	0.3	0.824
	760	54.4	1.145		10	2.5	0.602
	1429	83.9	1.231		50	5.0	1.000
	1029	67.5	1.183		29	5.0	0.763
	1885	105.5	1.252		97	16.7	0.764
	946	66.5	1.153		260	14.3	1.260
	1050	55.0	1.281		209	16.9	1.092
	627	58.4	1.031		221	10.8	1.311
	785	68.3	1.060		573	28.4	1.305
MEAN	1045	67.8	1.176	MEAN	134	9.6	0.927
1941	552	45.6	1.083	1945	184	18.5	0.998
	458	44.5	1.013		114	12.7	0.953
	506	46.4	1.038		556	21.5	1.413
	402	32.8	1.088		562	32.0	1.245
	231	29.5	0.894		273	30.6	0.950
	826	59.8	1.140		461	36.2	1.105
	1088	66.9	1.211		570	42.6	1.126
	1086	60.0	1.258		288	25.9	1.046
	1356	65.9	1.313		489	34.9	1.146
	911	46.3	1.294		1183	68.8	1.235
	697	38.3	1.260		432	46.0	0.973
	370	33.7	1.041		341	27.4	1.095
MEAN	707	47.5	1.136	MEAN	454	33.1	1.107
1942	410	35.6	1.061	1946	1151	47.6	1.383
	1033	52.8	1.291		2966	86.2	1.537
	920	54.2	1.230		1686	76.6	1.343
	1027	60.7	1.228		1469	75.7	1.288
	275	25.0	1.041		1048	84.9	1.091
	103	11.4	0.956		728	73.5	0.996
	214	17.7	1.082		2586	116.2	1.347
	282	20.2	1.145		2033	107.2	1.278
	157	17.2	0.960		1725	94.4	1.262
	261	19.2	1.133		1296	102.3	1.103
	508	30.7	1.219		1782	123.8	1.158
	314	22.5	1.145		2185	121.7	1.254
MEAN	459	30.6	1.124	MEAN	1721	92.5	1.253

TABLE I - MONTHLY SUNSPOT AREAS AND NUMBERS

YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1947	2036	115.7	1.245	1951	689	59.8	1.062
	2376	133.4	1.251		695	59.9	1.065
	3365	129.8	1.414		902	55.9	1.208
	3431	149.8	1.360		1569	92.9	1.228
	3716	201.3	1.266		2855	108.5	1.420
	1756	163.9	1.030		2420	100.6	1.381
	2496	157.9	1.199		866	61.5	1.149
	3217	188.8	1.231		806	61.0	1.121
	2174	169.4	1.108		1108	83.1	1.125
	2419	163.6	1.170		836	51.6	1.210
	1664	128.0	1.114		767	52.4	1.165
	1824	116.5	1.195		602	45.8	1.119
MEAN	2540	151.5	1.215	MEAN	1176	69.4	1.188
1948	1268	108.5	1.068	1952	515	40.7	1.102
	1107	86.1	1.109		334	22.7	1.168
	1290	94.8	1.134		219	22.0	0.998
	3395	189.7	1.253		438	29.1	1.178
	3213	174.0	1.266		265	23.4	1.054
	2542	167.8	1.180		438	36.4	1.080
	1935	142.2	1.134		649	39.3	1.218
	2174	157.9	1.139		784	54.9	1.155
	1785	143.3	1.095		358	28.2	1.104
	1665	136.3	1.087		410	23.8	1.236
	1091	95.8	1.056		492	22.1	1.348
	2405	138.0	1.241		486	34.3	1.151
MEAN	1989	136.2	1.147	MEAN	449	31.4	1.149
1949	1914	119.1	1.206	1953	333	26.5	1.099
	3234	182.3	1.249		15	3.9	0.585
	3274	157.5	1.318		78	10.0	0.892
	2021	147.0	1.138		477	27.8	1.234
	1399	106.2	1.120		207	12.5	1.219
	1624	121.7	1.125		271	21.8	1.095
	1736	125.8	1.140		122	8.6	1.152
	2278	123.8	1.265		322	23.5	1.137
	2245	145.3	1.189		177	19.3	0.962
	1831	131.6	1.143		63	8.2	0.886
	2328	143.5	1.210		11	1.6	0.837
	1507	117.6	1.108		10	2.5	0.602
MEAN	2116	135.1	1.184	MEAN	174	13.8	0.975
1950	1459	101.6	1.157	1954	0	0.2	0.0
	2049	94.8	1.335		2	0.5	0.602
	1760	109.7	1.205		174	10.9	1.203
	2396	113.4	1.325		7	1.8	0.590
	1649	106.2	1.191		1	0.8	0.097
	1174	83.6	1.147		0	0.2	0.0
	1371	91.0	1.178		19	4.8	0.598
	1221	85.2	1.156		74	8.4	0.945
	567	51.3	1.043		3	1.5	0.301
	648	61.4	1.023		36	7.0	0.711
	850	54.8	1.191		66	9.2	0.856
	712	51.4	1.142		128	7.6	1.226
MEAN	1321	83.7	1.174	MEAN	43	4.4	0.594

TABLE I - MONTHLY SUNSPOT AREAS AND NUMBERS

YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1955	626	23.1	1.433	1959	5050	217.4	1.366
	320	20.8	1.187		2712	143.1	1.278
	37	4.9	0.878		4442	185.7	1.379
	99	11.3	0.943		2897	163.3	1.249
	352	28.9	1.086		3212	172.0	1.271
	567	31.7	1.253		3674	168.7	1.338
	272	26.7	1.008		2698	149.6	1.256
	628	40.7	1.188		3688	199.6	1.267
	497	42.7	1.066		2814	145.2	1.287
	1094	58.5	1.272		1922	111.4	1.237
	1985	89.2	1.347		2621	124.0	1.325
	1173	76.9	1.183		2803	125.0	1.351
MEAN	638	37.9	1.154	MEAN	3211	158.7	1.300
1956	1648	73.6	1.350	1960	3021	146.3	1.315
	3242	124.0	1.417		2165	106.0	1.310
	2208	118.4	1.271		1767	102.2	1.238
	1748	110.7	1.198		2317	122.0	1.279
	2781	136.6	1.309		2528	119.6	1.325
	2043	116.6	1.244		1943	110.2	1.246
	2280	129.1	1.247		2321	121.7	1.280
	3598	169.6	1.327		2546	134.1	1.278
	2928	173.2	1.228		1941	127.2	1.184
	2821	155.3	1.259		1565	82.8	1.276
	4438	201.3	1.343		1992	89.6	1.347
	3835	192.1	1.300		1033	85.6	1.082
MEAN	2798	141.7	1.291	MEAN	2095	112.3	1.263
1957	2778	165.0	1.226	1961	914	57.9	1.198
	1700	130.2	1.116		350	46.1	0.880
	2128	157.4	1.131		585	53.0	1.043
	2480	175.2	1.151		677	61.4	1.042
	2984	164.6	1.258		446	51.0	0.942
	5094	200.7	1.405		921	77.4	1.076
	3713	187.2	1.297		1474	70.2	1.322
	2757	158.0	1.242		604	55.9	1.034
	5289	235.8	1.351		930	63.6	1.165
	5323	253.8	1.322		286	37.7	0.880
	3210	210.9	1.182		294	32.6	0.955
	4763	239.4	1.299		394	40.0	0.993
MEAN	3518	189.8	1.248	MEAN	656	53.9	1.044
1958	3885	202.5	1.283	1962	408	38.7	1.023
	3537	164.9	1.331		324	50.3	0.809
	5084	190.7	1.426		698	45.6	1.185
	4295	196.0	1.341		558	46.4	1.080
	3323	175.3	1.278		596	43.7	1.135
	3405	171.5	1.298		436	42.0	1.016
	4201	191.4	1.341		218	21.8	1.000
	3924	200.2	1.292		172	21.8	0.897
	4109	201.2	1.310		567	51.3	1.043
	3233	181.5	1.251		369	39.5	0.970
	2077	152.3	1.135		311	26.9	1.063
	3757	187.6	1.302		196	23.2	0.927
MEAN	3736	184.6	1.299	MEAN	404	37.6	1.012

TABLE I - MONTHLY SUNSPOT AREAS AND NUMBERS

YEAR	AW	RZ	LOG(AW/RZ)	YEAR	AW	RZ	LOG(AW/RZ)
1963	272	19.8	1.138	1967	1661	110.9	1.175
	258	24.4	1.024		1299	93.6	1.142
	235	17.1	1.138		2161	111.8	1.286
	343	29.3	1.068		643	69.5	0.966
	634	43.0	1.169		1504	86.5	1.240
	450	35.9	1.098		903	67.3	1.128
	202	19.6	1.013		1302	91.5	1.153
	460	33.2	1.142		1846	107.2	1.236
	235	38.8	0.782		737	76.8	0.982
	574	35.3	1.211		1425	88.2	1.208
	270	23.4	1.062		1273	94.3	1.130
	101	14.9	0.831		1576	126.4	1.096
MEAN	336	27.9	1.056	MEAN	1361	93.7	1.145
1964	199	15.3	1.114	1968	1752	121.8	1.158
	241	17.7	1.134		1291	111.9	1.062
	264	16.5	1.204		1110	92.2	1.081
	20	8.6	0.367		959	81.2	1.072
	68	9.5	0.855		1734	127.2	1.135
	68	9.1	0.873		1816	110.3	1.217
	17	3.1	0.739		1512	96.1	1.197
	126	9.3	1.132		1889	109.3	1.238
	18	4.7	0.583		1339	117.2	1.058
	37	6.1	0.783		1620	107.7	1.177
	114	7.4	1.188		1313	86.0	1.184
	134	15.1	0.948		1432	109.8	1.115
MEAN	109	10.2	0.910	MEAN	1481	105.9	1.141
1965	237	17.5	1.132	1969	1779	104.4	1.231
	128	14.2	0.955		856	120.5	0.851
	109	11.7	0.969		1989	135.8	1.166
	44	6.8	0.811		1283	106.8	1.080
	267	24.1	1.044		1388	120.0	1.063
	161	15.9	1.005		1192	106.0	1.051
	49	11.9	0.615		1194	96.8	1.091
	50	8.9	0.750		1036	98.0	1.024
	222	16.8	1.121		812	91.3	0.949
	189	20.1	0.973		1726	95.7	1.256
	134	15.8	0.928		2186	93.5	1.369
	252	17.0	1.171		1193	97.9	1.086
MEAN	154	15.1	0.956	MEAN	1386	105.6	1.101
1966	337	28.2	1.077	1970	1627	115.4	1.149
	297	24.4	1.085		2281	129.8	1.245
	558	25.3	1.344		1185	101.7	1.066
	879	48.7	1.256		1912	109.1	1.244
	405	45.3	0.951		2110	131.1	1.207
	282	47.7	0.772		1504	106.8	1.149
	650	56.7	1.059		1415	112.5	1.100
	576	51.2	1.051		1076	92.9	1.064
	653	50.2	1.114		1477	98.8	1.175
	535	57.2	0.971		1177	85.0	1.141
	644	57.2	1.051		1952	91.1	1.331
	915	70.4	1.114		1274	76.6	1.221
MEAN	561	46.9	1.071	MEAN	1583	104.2	1.174